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BRIEF SHORT TITLE: Emotional processing and blood pressure

**Poor Emotional Responsiveness in Clinical Hypertension: Reduced Accuracy in the Labelling and Matching of Emotional Faces amongst Individuals with Hypertension and Prehypertension**

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## **Abstract**

Psychological factors are known to play an important part in the origin of many medical conditions including hypertension. Recent studies have reported elevated blood pressure (even in the normal range of variation) to be associated with a reduced responsiveness to emotions or ‘emotional dampening’. Our aim was to assess emotional dampening in individuals with more extreme blood pressure levels including prehypertensives (N=58) and hypertensives (N=60) by comparing their emotion recognition ability with normotensives (N=57). Participants completed novel facial emotion matching and facial emotion labelling tasks following blood pressure measurement and their accuracy of emotion recognition and average response times were compared. The normotensives demonstrated a significantly higher accuracy of emotion recognition than the prehypertensives and the hypertensives in labelling of facial emotions. This difference generalized to the task where two facial halves (upper & lower) had to be matched on the basis of emotions. In neither the labelling nor matching emotion conditions did the groups differ in their speed of emotion processing. Findings of the present study extend reports of ‘emotional dampening’ to hypertensives as well as those at-risk for developing hypertension (i.e., prehypertensives) and have important implications for understanding the psychological component of such medical conditions as hypertension.

*Keywords:* emotional dampening, blood pressure, facial emotion, implicit, explicit

## Introduction

Hypertension is a leading cause of cardiovascular complications and a topmost risk factor for mortality (Forouzanfar et al, 2016). Recognized as a disease taking on the form of a global epidemic (Chockalingam, Campbell, & Fodor, 2006), it is imperative to identify the mechanisms underlying hypertension in order to formulate measures to control it. Though the etiology and pathophysiology of hypertension is likely involves an interplay between genetic factors, neural mechanisms and endocrine functioning, cardiac and renal functions, environmental, adaptive, hemodynamic and anatomical factors (Page, 1967; 1982), recently psychological factors have been recognized to be as important in the maintenance, development and management of psychosomatic conditions (Jennings & Heim, 2012) such as hypertension. Here, we examine the link between emotion processing and hypertension.

That psychological factors contribute to hypertension is supported by clinical, epidemiological and laboratory research evidence showing linkages between emotional mood states or trait-like dispositions and blood pressure (Esler & Parati, 2004). For example, data from cross-sectional epidemiological studies show associations between hypertension and anxiety (e.g., Jonas, Franks, & Ingram, 1997; Ginty, Carroll, Roseboom, Phillips & de Rooij, 2013), hostility (Yan, et al., 2003), anger (Player, King, Mainous, & Geesey, 2007), depression (Simonsick, Wallace, Blazer, & Berkman, 1995), Type A behaviour pattern (Yan et al., 2003), and alexithymia (e.g., Grabe et al, 2010). While these cross-sectional studies cannot disentangle whether psychological variables precede or follow hypertension, prospective and longitudinal studies point towards anger, anxiety, and depression as precursors to the development of hypertension (Player et al, 2007; Everson, Goldberg, Kaplan, Julkunen & Salonen, 1988; Ginty et al, 2013; Bacon, Campbell, Arsenault, & Lavoie, 2014; Carroll, Phillips, Gale, & Batty, 2010; Pratt et al, 1996). Other studies have

also shown that emotional processing was impaired to a greater extent in individuals with essential hypertension than in patients with secondary hypertension (e.g., Consoli, 2010).

Together, these data tentatively suggest a role for emotion processing difficulties in the origin of hypertension. However, there is also no dearth of researchers who argue that elevated blood pressure or hypertension may have a causative role in disrupted affective processing. That is, the association with emotional mood states and trait-like dispositions are a consequence of living with a chronic health condition. For instance, Wei and Wang (2006) found a 3-year history of hypertension to be an independent predictor of anxiety. Similarly, a longitudinal study showed that people with elevated blood pressure have a higher incidence of depression (Zhang et al, 2006). On the other hand, some researchers posit that both elevated blood pressure and emotion processing difficulties affect each other in a cyclic manner, leading to further elevations in both blood pressure and emotional difficulties over time. Thus, poor emotional processing may result in inappropriate emotional communication in relationships, creating social distancing and stress, which in turn may further increase blood pressure and result in more emotion processing difficulties (McCubbin et al, 2011; McCubbin et al, 2013). A similar cyclic mechanism is implied by the Polyvagal theory (Porges, 1995) which holds that reciprocal connections between the brain and heart provide an inhibitory pathway to slow down heart rate and lower blood pressure, promoting the calm state necessary to express social engagement behaviors and emotional regulation. Regardless of the direction of causality in the hypertension-emotion processing relationship, what is clear is that emotion processing difficulties can complicate the management of elevated blood pressure and hypertension. (e.g. Trivedi, Ayotte, Edelman, & Bosworth, 2008) Thus research efforts to understand their nature and extent in relation to blood pressure are crucial.

In support of this view, many studies have begun to examine the link between elevated blood pressure and emotion processing using performance-based measures rather

than simply self-reported questionnaires as previous studies had done. Consistent with a well-established literature suggesting that hypertensives show attenuated responses to pain (France, 1999; Ghione, 1996), these studies also suggest a more general reduction in emotional responsiveness (Pury, McCubbin, Helfer, & Galloway, 2004; McCubbin, Merritt, & Sollers, et al, 2011; McCubbin, et al, 2013). Similar findings were reported by another group of researchers who extended the previous findings of emotional dampening to an aged sample (mean age 52.8 years) of African-Americans (McCubbin, et al., 2011) belonging to a low socio-economic status and therefore at an increased risk of developing hypertension. They reported dampening to emotional content in faces and written narrative sentences in persons with high resting BP and Total Peripheral Resistance. Another study on emotional dampening reported that resting diastolic blood pressure was correlated negatively with emotion recognition accuracy in men (McCubbin, et al, 2013). Furthermore, normotensives with a parental history of hypertension also demonstrate reduced responsivity to both positive and negative emotions in comparison to individuals with normotensive parents (Wilkinson & France, 2009). These emotional dampening have been attributed to the mechanisms implicated in blood pressure-induced hypoalgesia (or reduced perception of pain) such as the opioid and baroreflex system (Ghione, 1996; France, 1999; Bruehl & Chung, 2004; McCubbin, Helfer, Switzer, Galloway, & Griffith, 2006). However, a more recent study showing no association between emotion recognition accuracy and blood pressure (or heart rate variability) (Loveless, 2015), highlight the subtlety of the phenomenon and need for further research.

To date all of the studies to our knowledge have been conducted in individuals with elevated blood pressure in the normal range and not yet in individuals with clinical hypertension. Moreover, the nature of these deficits is unclear as almost all studies have used static emotional stimuli (facial affect photographs or affect-inducing scenes) in

‘explicit’ affect-labelling experimental tasks and have overlooked the likelihood that in real life one encounters dynamic emotional stimuli, which are processed at a more ‘implicit’, or automatic, level rather than being labelled. The present study addressed these gaps in the literature by examining and comparing emotion recognition in a group of normotensive, prehypertensive, and hypertensive participants on two distinct emotion processing tasks. On the first, participants were required to complete a task that involved labelling the emotion displayed in an animated face (an ‘explicit’ task of emotion recognition). On the second, participants were instructed to match the emotion displayed in a target face with one of 4 possible faces displaying different emotions (an ‘implicit’ task of emotion recognition). We hypothesized that hypertensives would perform significantly worse than those in the normotensive range (and that this would be evident in accuracy on the task or response time, or both). Tentatively, we also predicted a dose-response relationship such that prehypertensives would perform intermediate to the other two groups.

## **Method**

### ***Participants***

The participants in this study comprised 57 normotensive, 58 prehypertensive, and 60 hypertensive (see Table 1 for demographic information) Asian-Indian adults belonging to the middle socio-economic status. The socio-economic status of the participants was defined as the monthly per capita income of the participants in accordance with the criteria set out in the BG Prasad socioeconomic classification, which is specific to India (Khairnar, Wadgave, & Shimpi, 2016). Participants in the three groups were recruited following the criteria stated in the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC-7, 2003; Chobanian, 2003). Based on the said criteria, the normotensive group comprised individuals with SBP < 120 mmHg and DBP < 80 mmHg; pre-hypertensives had SBP between 120-139 mmHg and/or DBP in the range 80-89

mmHg, and individuals categorized as hypertensives had SBP  $\geq$  140 mmHg and/or DBP  $\geq$  90 mmHg. We excluded individuals who smoked daily or consumed alcoholic beverages, and who were currently or previously taking medication for their hypertension or any other chronic physical or mental health problem. Other exclusion criteria were a diagnosed mental disorder, a history of mental illnesses, any physical disease condition (such as thyroid problems, kidney problems, heart condition, etc.) vision or hearing problems, undergoing any treatment for other physical or mental health condition, pregnancy or lactation.

The participants were recruited from the out-patient unit of the cardiology department of the Institute of Medical Sciences, Banaras Hindu University. Individuals diagnosed as hypertensives for the first time on their arrival to the out-patient department (OPD) were included in the hypertensive category after their consent to participate in the study. The normotensives and the prehypertensives were the family members or other relatives of the hypertensive individuals who accompanied them to the OPD and consented to participating in the experiment. Ethics approval for this research study, including the methods and procedure to be followed, was provided by the Ethics Committee, Institute of Science, Banaras Hindu University (*Ref No.: I.Sc./ECM-IX/2016-17/02*). Informed consent was obtained from all individual participants included in the study.

### ***Measures***

A standard mercury sphygmomanometer, still considered the gold standard for BP measurement (O'Brien et al, 2003; Pickering, 2005), was used to take blood pressure measurements of the participants in accordance with the guidelines provided by the JNC-7. In addition, participants completed two experimental tasks.

Two tasks presented in Paradigm software (v 2.4.0.191) were administered. For the first, we used emotion videos to tap participants' ability to correctly label emotions displayed through facial expressions. For the second, we presented participants with a matching task



which aimed at assessing the recognition of emotions without prompting the participants explicitly to name the emotions presented. The task involved matching the upper half of an emotional face video to its corresponding lower half. The task was such that accurate matching would entail recognizing emotions presented in the two facial halves correctly and would thus inform the accuracy of implicit emotion recognition of the participants. Apart from the accuracy of emotion recognition in both the explicit and implicit conditions, we were also interested in the response times taken by the participants on these tasks. We chose accuracy as an indicator of emotion recognition in keeping with the earlier studies of emotional dampening (McCubbin et al, 2011; McCubbin et al, 2013). We chose response time (RT) as an index of emotion recognition as it has greater sensitivity than response accuracy as an indicator of the underlying processes (Sternberg, 2004). Thus, we hypothesized that an increase in reaction time to correctly identify emotions would indicate a slower but preserved recognition of facial emotions.

The facial emotion videos were developed from standardized static facial images taken from Cohn-Kanade AU-Coded Facial Expression Database (Kanade, Cohn, & Tian, 2000; Lucey et al, 2010). The complete database includes approximately 2000 image sequences from about 200 posers. The part of the database that has been made available for the free use of researchers comprises 97 possible faces of actors in the age range of 18-30 years. The database contains a series of posed facial photographs ranging from neutral to the target emotion for the 7 emotion categories of Anger, Contempt, Disgust, Fear, Happy, Sadness and Surprise. All the final images in the sequence for each emotion display the full possible action units for that emotion. Action units refer to the anatomical contractions of specific facial muscles that comprise each of the full expressions for that emotion (Ekman & Friesen, 1978). As each emotion changes from neutral to full intensity, increasingly more action units are displayed. Actors were instructed to display increasingly more action units as

they moved from a neutral emotion to the full expression of a particular emotion. We therefore relied on the number of action units displayed for any given emotion to reflect intensity for that emotion, rather than intensity ratings per se. However, only final image (full expression) for each image sequence has been standardized. Specifically, the target emotion photograph of each series was coded by skilled FACS (Facial Action Coding System) coders. Fifteen percent of the photographs were comparison coded by another FACS coder and then an inter-observer agreement was calculated (see Kanade et al, 2000 & Lucey et al, 2010 for more details). Image sequences from four posers (2 males, 2 females), each displaying six basic emotions were chosen from the database for use in the present study. The choice of the posers was based on pragmatic considerations. For instance, only posers with standardized image sequences for all of the six basic emotion categories were considered. Secondly, since the dataset includes different number of still facial photographs for different posers from the neutral to the target emotion, only such posers with roughly equal numbers of photographs for each emotion category ranging in intensity from neutral to the full display of target emotion were selected.

*Explicit Task of Emotion Recognition: Labelling emotions in faces*

In this task participants were presented with full face videos of emotional expressions and verbally instructed to choose the emotion label that best described the emotion expressed in the facial emotion video. They were instructed to respond as fast and as accurately as possible. Photos used in this task (*Fig. 2(a)*) were developed by combining the full face image sequences ranging from neutral to target emotion in Windows Movie Maker. Full face videos displaying different emotions appeared in the upper centre of the computer screen with four response options (Hindi names of the emotions) given below. One of the labels was the correct response option denoting the emotion expressed in the facial video while the remaining three were the distractor labels. Participants indicated their responses by pressing

the numeric keys (from 1 to 4) from the keyboard. The task comprised 24 trials and the videos within each trial were on a continuous loop until the participant entered a response. RTs were recorded for when the participant made a manual response.

*Implicit Task of Emotion Recognition: Matching emotions in faces*

The implicit visual emotion recognition task (*Fig. 2(b)*) comprised of a target upper face with four lower face videos as response choices, and participants were required to select the lower face video that would best match the face presented in the target video. Due care was taken not to explicitly tell the participants to match the facial halves on the basis of the emotion expressed in them. This task used photographs of the same posers as used in the explicit task. For implicit task, image sequences from the chosen 4 posers were split horizontally from the middle dividing the face into upper and lower halves. All the upper face images for each emotion sequence (ranging from neutral to the full emotion display) were combined to form upper face videos while all the lower face images for each emotion sequence were combined to form lower face videos (see *Fig 1*). As with the explicit task, these videos were developed in Windows Movie Maker. The target and the response faces were from the same poser, only the emotion posed differed in three of the response choices while the fourth portrayed the same emotion as in the target. The task comprised 24 trials and the videos within each trial were on a continuous loop until the participant entered a response. The response was a numeric key press between 1 and 4. Since RT was also a variable of interest, participants were asked to respond as quickly and as accurately as possible.

[Figures 1, 2a and Figure 2b here]

## Procedure

The study was conducted in a quiet room adjoining the cardiology OPD so that the availability of a cardiologist could be ensured in case any untoward physical situation occurred with the participants during the course of the experiment. All participants had been instructed not to consume any caffeinated or alcoholic drinks or performed vigorous exercise for about 2 hours prior to the experiment. When the participants arrived to the experimental session, they were requested to relax in a comfortable chair for approximately 10 minutes so that their blood pressure would normalize. Following this rest period, the blood pressure of the participants was measured using a mercury sphygmomanometer by a trained cardiologist. Three BP readings were taken, with each successive reading taken after about 2 minutes of the previous reading, consistent with the guidelines given by JNC-7 for accurate measurement of BP. The average of the three readings was used to classify participants into either of the three groups, i.e. normotensives, prehypertensives, and hypertensives. Participants were then requested to sit in a chair facing the laptop to complete the experimental tasks. It was checked whether participants had normal or corrected-to normal vision and could identify the stimuli presented on the laptop. They were given all the necessary information about the study and then a written informed consent was obtained from them before beginning the experiment.

For all the participants, the implicit task was administered first followed by the explicit task. Participants were given verbal instructions on how to complete each task along with a simultaneous on-screen presentation of instructions. After ensuring that the participants clearly understood the instructions by asking them to restate in their own words what they were required to do, a practice session was given to them on three trials. Any doubt or query of the participants arising from the practice session was resolved before beginning the administration of the main experimental session. The presentation of the trials was

randomized across participants. Participants were allowed a rest pause of 10 minutes between tasks. On completion of the explicit task, participants were debriefed regarding the purpose of the study and thanked for their participation.

### *Statistical analysis*

The Independent Variable (IV) in the present study was blood pressure category, with three levels: normotensives, prehypertensives, and hypertensives. There were four Dependent Variables (DVs) namely implicit emotion recognition accuracy, explicit emotion recognition accuracy, average RT for implicit emotion recognition, and average RT for explicit emotion recognition. The accuracy of emotion recognition for both the implicit and explicit tasks was calculated as the percentage of the total number of items that were correctly responded to. The average RT was computed as the mean of RTs for correct responses. Univariate Analysis of Covariance (ANCOVA) was applied on each DV separately. The effect of relevant variables such as age, gender and education was controlled for by entering them as covariates in the analysis. In case of significant effects of age and education on the dependent variables, a correlation of age and education was computed to see the direction of association of these continuous variables with the dependent variables.

However, as age was significantly different across groups, and as it also significantly associated with all of our DVs, we also repeated ANOVAs using a smaller sub-sample of participants from the three groups, but who were matched on age. This matching was done by excluding participants of a particular age from one BP group, who did not have at least one other participants of the same age in the remaining two BP groups. This was done to verify that the same pattern of results was obtained after removing the confounding effect of age through matching rather than simply statistically controlling. However, this meant conducting analysis with a smaller sample size and reduced statistical power. Finally, partial correlations

were used to examine the continuous relationship between blood pressure and emotion recognition accuracy and RTs across groups, controlling for age, gender and education.

## Results

The average resting SBP and DBP values for the three groups are presented in Table 1 along with the age, gender, and education level of the participants. In terms of the age of the participants, each of the three groups of normotensives, prehypertensives, and hypertensives differed significantly from the other group,  $F(2, 172) = 78.65, p < .001$  (Table 1). The mean age of the hypertensive group was the highest, followed by prehypertensives and normotensives. Significant differences were also observed in the gender composition of normotensive (11 males, 46 females), prehypertensive (31 males, 27 females) and hypertensive (42 males, 18 females) groups,  $\chi^2(2, N=175) = 31.14, p < 0.001$ . It was found that normotensives differed significantly in gender composition from the prehypertensives ( $p < 0.001$ ) and the hypertensives ( $p < 0.001$ ), but no significant difference was seen to exist between prehypertensives and hypertensives with regard to gender composition. Normotensives had significantly higher number of females and lower number of males than the other two groups. Similarly, the groups differed significantly in terms of their education level,  $F(2, 172) = 15.50, p < .001$  (Table 1). Normotensives received more years of formal education, than hypertensives ( $p < 0.001$ ) who received more years than prehypertensives ( $p < 0.001$ ). Normotensives and prehypertensives did not differ in education level. Age, gender and education were all included as covariates in subsequent analysis.

[Table 1 here]

Mean accuracy and RTs for each task for each group are presented in Table 2. On the **explicit task**, the results of the univariate ANCOVA on **accuracy scores** revealed significant effects of BP category,  $F(2, 169) = 3.88, p < .05; \eta^2p = .044$ , such that compared to the normotensives, the hypertensives demonstrated a significantly reduced emotion recognition

( $p < .05$ ) as did the prehypertensives ( $p < .01$ ). The latter two groups though did not differ among themselves in terms of the accuracy of emotion recognition,  $p = 0.90$ . There were also significant effects of age,  $F(1, 169) = 11.15$ ,  $p < 0.001$ ;  $\eta^2 p = .062$ , and education,  $F(1, 169) = 9.17$ ,  $p < 0.01$ ;  $\eta^2 p = .051$ , but not gender,  $F(1, 169) = 0.11$ ,  $p = 0.74$ ;  $\eta^2 p = .001$ , on the accuracy of explicit emotion recognition. Young participants had greater explicit emotion recognition accuracy scores than older participants ( $r = -0.47$ ,  $p < 0.001$ ), and participants with a higher education level had greater explicit emotion recognition accuracy scores than participants with a lower education level ( $r = 0.36$ ,  $p < 0.001$ ). There was no significant effect of gender on emotion recognition accuracy. Nor was the blood pressure x gender interaction significant.

[Table 2 here]

For **RTs** on the **explicit task**, there were no main effects of BP category,  $F(2, 169) = 1.08$ ,  $p = 0.34$ ;  $\eta^2 p = .013$ . However a significant effect of age,  $F(1, 169) = 40.51$ ,  $p < .001$ ;  $\eta^2 p = .193$ , and education,  $F(1, 169) = 13.06$ ,  $p < .001$ ;  $\eta^2 p = .072$ , but no effect of gender,  $F(1, 169) = 0.12$ ,  $p = 0.74$ ;  $\eta^2 p = .001$ , emerged on the RT of explicit emotion recognition. Thus, older participants took longer RTs for explicit emotion recognition than younger participants ( $r = 0.62$ ,  $p < 0.001$ ), and participants with a higher education level took shorter response times than those with a lower education level for explicit emotion recognition ( $r = -0.39$ ,  $p < 0.001$ ). The covariates did not significantly interact with BP on RT.

On the **implicit task**, the results of the univariate ANCOVA revealed that BP category significantly affected the **accuracy** of emotion recognition  $F(2, 169) = 7.42$ ,  $p < .001$ ;  $\eta^2 p = .081$ . Post-hoc comparisons using the LSD test indicated that the hypertensives demonstrated significantly reduced emotion recognition than the normotensives ( $p < .001$ ). Similarly, the prehypertensives performed significantly poorly on implicit emotion recognition task as compared to the normotensives ( $p < .01$ ). The hypertensives also demonstrated a significantly poorer emotion recognition accuracy than the prehypertensives

( $p < .05$ ). There were also significant effects of age,  $F(1, 169) = 40.68$ ,  $p < 0.001$ ;  $\eta^2p = .194$ , and education,  $F(1, 169) = 8.20$ ,  $p < 0.01$ ;  $\eta^2p = .046$ , on the accuracy of implicit emotion recognition, such that younger participants demonstrated significantly better recognition of emotions than the older ones ( $r = -0.68$ ,  $p < 0.001$ ) and those with higher education had a higher accuracy of implicit emotion recognition than those with lower education levels ( $r = 0.40$ ,  $p < 0.001$ ). No significant effect of the covariate gender,  $F(1, 169) = 0.33$ ,  $p = 0.57$ ;  $\eta^2p = .002$ , was observed on this outcome measure. Nor did BP interact significantly with gender.

There was no effect of BP on the **RT** of the participants on the **implicit task**,  $F(2, 169) = 0.35$ ,  $p = 0.71$ ;  $\eta^2p = .004$ . There was a significant effect of age on the RT on implicit emotion recognition,  $F(1, 169) = 7.95$ ,  $p < .01$ ;  $\eta^2p = .045$ . The older participants took longer RTs than younger participants for implicit emotion recognition ( $r = 0.29$ ,  $p < 0.001$ ). The covariates gender,  $F(1, 169) = 0.75$ ,  $p = 0.39$ ;  $\eta^2p = .004$ , and education,  $F(1, 169) = 0.93$ ,  $p = 0.34$ ;  $\eta^2p = .005$ , did not have a significant effect on RT of implicit emotion recognition. The interactions of the covariates with BP were not significant.

Because age was systematically associated with all of our DVs, and varied significantly across groups, we also repeated these analyses using a smaller subsample of our participants, but who were matched for age across groups. This resulted in 19 normotensives, 39 prehypertensives and 18 hypertensives. Repeating the analysis of group differences on the accuracy of emotion recognition in explicit and implicit tasks revealed similar patterns of group differences (see Table 2). Although these group differences were statistically-significant for the implicit task, the group differences failed to reach significance on the explicit task, perhaps due to a reduction in sample size.

Partial correlations of SBP and DBP (controlling for the effects of age, gender, and education) with the accuracy and RTs on the implicit and explicit tasks revealed significant negative correlations of SBP with accuracy of emotion recognition on the implicit task,  $r = -$



.176,  $p=.02$ , and between DBP with the accuracy of emotion recognition on the implicit task,  $r= -.204$ ,  $p=.007$ . Correlations with explicit task accuracy were not significant. Nor were correlations between BP and RTs on either task.

## Discussion

The present study explored the presence of emotional dampening in clinical hypertension as well as those at-risk for hypertension i.e. individuals with prehypertensive ranges of blood pressure. Individuals with hypertension and pre-hypertension performed worse than normotensives in terms of accuracy across two tasks: one which involved an explicit labelling of emotions displayed by faces and one which involved matching two halves of a face for equivalence in emotional expression. Interestingly, on the latter task, there was some support for a dose-response relationship such that hypertensives demonstrated worse performance compared to the prehypertensives. Consistent with this, both systolic and diastolic blood pressure correlated inversely with the accuracy of emotion recognition on the implicit task only indicating a successive decline in the capacity of emotion recognition with increase in blood pressure. Group differences only characterised indices of accuracy rather than speed of emotional processing.

A novel aspect of our study is that it extends earlier findings of emotional dampening in normotensive individuals with varying blood pressure elevations (Pury et al, 2004; McCubbin et al, 2011; McCubbin et al, 2013) to individuals in the clinical hypertensive range, as well as those who are at-risk (pre-hypertensives). Another novel aspect of our study is the use of dynamic facial emotion stimuli, which are closer to real life emotion recognition situations and the use of RT measures in addition to measures of emotion recognition accuracy as used in earlier studies. Earlier studies have largely used static emotional stimuli in the form of facial affect photographs or affect-inducing scenes in explicit affect labelling experimental tasks (Pury et al, 2004; McCubbin et al, 2011; McCubbin et al, 2013) and have

overlooked the likelihood that in real life one encounters dynamic emotional stimuli. Not only is the use of dynamic stimuli a more naturalistic approach to study emotion perception, but dynamic stimuli also entail more efficient processing (Mayes, Pipingas, Silberstein, Johnston, 2009). In fact, use of dynamic stimuli to study facial emotion recognition is encouraged as dynamic facial stimuli have been shown to enhance the performance of not just healthy controls but of patient groups as well (Atkinson, Dittrich, Gemmell, & Young, 2004; Tomlinson, Jones, Johnston, Meaden, & Wink, 2006; Schaefer, Baumann, Rich, Luckenbaugh, Zarate, 2010). Finally, by including an explicit measure of emotion recognition as prior studies, but also an implicit measure, our tasks served to probe the full range of emotional experiences. This is because emotional experiences can be both conscious and reportable (Bartoszek, 2009), and yet can also be experienced sub-consciously and not always outwardly reportable (Weinberger, Kelner, & McClelland, 1997).

However, there are also certain limitations of the present study. One of the primary limitations is that point measurements of blood pressure on just one occasion were used to classify the participants into one of the three groups. As per the guidelines of JNC-7, the blood pressure readings of the participants should be averaged over two or more measurements on each of two or more office visits. However, earlier studies on emotional dampening have considered BP reading recorded on a single occasion thus our methods are therefore consistent with them. A second limitation is that participants across the three groups differed significantly on age and education – variables that were also significantly associated with the dependent variables of emotion labelling and matching accuracy. Although we were able to control for these confounding factors, and for age we created matched (albeit smaller) sub-samples of each group to reveal similar patterns of findings, we were unable to do this for education given that all participants of the normotensive group were largely university students. Relatedly, although gender was not found to interact with BP or have a significant

effect on any of the outcome measures, the difference in gender composition across the BP groups is a limitation. Future studies should aim to recruit matched samples on age, gender and education. A third limitation is that we relied on task performance to reflect emotion-processing rather than autonomic data. Also a weakness of the task was that participants in this study belonged to a different race from that of the posers of the emotion photographs. Cross-race effects that prevail in situations where people belonging to one race are required to identify emotional displays of other race, may have led to less accurate and slower recognition of the facial emotion expressions in this task (Elfenbein & Ambady, 2002). The generally reduced emotion recognition accuracy (approx. 71.37%) of the participants with BP within the normal range across both the tasks may be a manifestation of this cross-race effect. Fifth, the reduced accuracy of emotion recognition in the implicit relative to the explicit task in normotensive individuals suggests that the implicit condition might be tapping into a different cognitive schema with regard to perception of emotion expression than the explicit task. This may limit our ability to generalise findings about emotion recognition across tasks. Finally, there was a discrepancy between group differences on accuracy and RT. While not a study limitation as such, future studies need to establish whether this is a real difference or a design-related artefact. As RT differences tap more subtle differences in how information is processed, rather than inaccurately processed, it seems from our data that hypertension-related differences in emotion recognition are much more overt.

### ***Mechanisms and implications***

The findings of this study provide important insights into the possible mechanisms implicated in the development of hypertension. Researchers have reported that sympathovagal disturbances resulting from vagal inhibitions are responsible for progression from prehypertension to hypertension (Pal et al, 2011). Studies have also shown an increase in vagal tone linked with adaptive emotional responding (Porges, 1991) and stress resilience

(Fabes, 1997). Therefore, decrease in vagal tone could be associated with poor (or maladaptive) emotional responding, i.e. emotional dampening. In fact, abnormal vagal regulations in other clinical populations have been linked with poor processing of emotional information in faces and voices (Heilman, Harden, Weber, Cohen, & Porges, 2013; Porges et al, 2013). Since vagal inhibitions are linked to progression from prehypertension to hypertension and to poor emotional responding, this mechanism might be the link between elevated BP and emotional dampening. Another finding supporting this speculation is that low heart rate variability (HRV; an index of vagal tone) is found to be associated with poor regulatory control of the prefrontal cortex over subcortical processes (Thayer, Hansen, Saus-Rose, & Johnsen, 2009). This might explain why increase in resting BP of the participants in our study resulted in poorer implicit and explicit processing of emotions. Thus, emotional dampening may be intricately embedded in the baroreflex (McCubbin et al, 2013) and vagal mechanisms (Porges et al, 1995) associated with BP elevations.

Although our sample did not include hypertensives on medication and cannot speak to this question, a major obstacle in achieving blood pressure control is non-adherence to lifestyle modifications and medications (Jin, Sklar, Oh, & Li, 2008). Non-adherence could potentially arise from emotional dampening. Extant research has investigated the factors responsible for such non-compliance and one of the most important ones appear to be the lack of good patient-physician relationship and emotional support from family (Moore, Sickel, Malat, 2004; Gonzalez et al, 2005; Costa & Nogueira, 2008). Given the present findings of emotional dampening in hypertensive patients, an impairment in recognizing and understanding of the emotions of others and failure to correctly respond to their emotional expressions are likely to create distance in relationships (e.g., Porges & Furman, 2011). This may then contribute to deteriorating quality of their emotional bonding with their physicians, and family members, and therefore non-compliance. Clearly, these causal

relationships require empirical verification but if they are supported, they suggest that therapeutic interventions for hypertensives should address their emotional difficulties which may improve treatment compliance by enhancing the emotional quality of patients' relationships with significant others. On similar lines, a poor quality of emotional relationship with their physicians and family members may imply an increased non-compliance with lifestyle modifications in people at risk of developing hypertension (i.e., prehypertensives) and may thus increase their chances of developing hypertension. Therefore, recommendations of lifestyle modifications for prehypertensives should also incorporate interventions for improving emotion processing.

## **Conclusion**

The present findings provide support to the emotional dampening hypothesis and add to the existing literature by extending these effects beyond the normotensive range to the prehypertensive and the hypertensive ranges of elevated blood pressure. These findings also show that emotional dampening manifests in both the implicit and explicit modes of emotional processing and across both the genders. Future investigations focussed on the link between blood pressure and emotional recognition should explore emotional dampening using more precise BP measurements and psychophysiological indices of emotion-processing (and autonomic functioning). Exploring if individuals with secondary hypertension experience similar emotion-related difficulties as those with essential hypertension would also help inform the causal mechanism of emotional dampening.

**Conflict of Interest:** The authors declare that they have no conflict of interest.

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**Figure legends:**

Figure 1: Schematic of the process of developing the facial emotion videos for the Implicit Visual Emotion Recognition Task

Figure 2a (*Left*): Schematic of Explicit Visual Emotion Recognition Task (Images © Jeffrey Cohn)

Figure 2b (*Right*): Schematic of Implicit Visual Emotion Recognition Task

Table 1: Overall and group-wise demographic information of the participants

a, b, c= Common superscripts denote no significant difference between means

	<u>Blood Pressure Groups</u>			
	Overall sample (N=175)	Normotensives (N=57)	Prehypertensives (N=58)	Hypertensives (N=60)
Age range (years)	19-62	20-41	19-60	20-62
Avg. Age (years)	34.73 ± 14.09	23.95 <sup>a</sup> ± 3.92	32.29 <sup>b</sup> ± 12.41	47.33 <sup>c</sup> ± 11.93
Gender (Female)	91	80.70%	46.55%	30%
Education (years)	14.73 ± 3.68	16.32 <sup>a</sup> ± 2.73	15.09 <sup>a</sup> ± 2.81	12.87 <sup>b</sup> ± 4.37
SBP (mmHg)	125.81 ± 22.58	104.07 ± 9.16	122.02 ± 9.25	150.12 ± 16.44
DBP (mmHg)	81.87 ± 11.94	69.11 ± 6.43	82.22 ± 4.32	93.65 ± 8.01

Table 2: The effect of B P category on accuracy (in %) and RT (in *ms*) of emotion recognition in the implicit and the explicit conditions

DVs	<u>Blood Pressure Category</u>			F <sub>(2,169)</sub>
	Normotensives	Prehypertensives	Hypertensives	
	Mean (SD)	Mean (SD)	Mean (SD)	
Accuracy_Implicit	64.02 (17.44)	55.67 (14.10)	49.33 (18.23)	7.42***
Accuracy_Explicit	78.72 (15.71)	71.66 (12.69)	71.29 (16.40)	3.88*
RT_Implicit	11305.46 (6265.33)	11614.04 (5058.86)	10708.91 (6540.14)	0.35
RT_Explicit	6217.53 (2758.70)	6883.44 (2227.48)	6738.44 (2879.70)	1.08
DVs	<u>Groups matched on age</u>			F <sub>(2,169)</sub>
	Normotensives (N= 19)	Prehypertensives (N= 38)	Hypertensives (N=18)	
	Mean (SD)	Mean (SD)	Mean (SD)	
Accuracy_Implicit	70.49 ( 18.49)	60.16 ( 14.97)	50.79 ( 16.83)	4.50*
Accuracy_Explicit	80.31 ( 15.56)	73.98 ( 12.60)	71.37 ( 14.17)	1.40

\*p &lt; .05, \*\*\*p&lt;.001